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Planetary Defense

Asteroids, Comets, Impact Craters, and
Outwitting the Dinosaurs

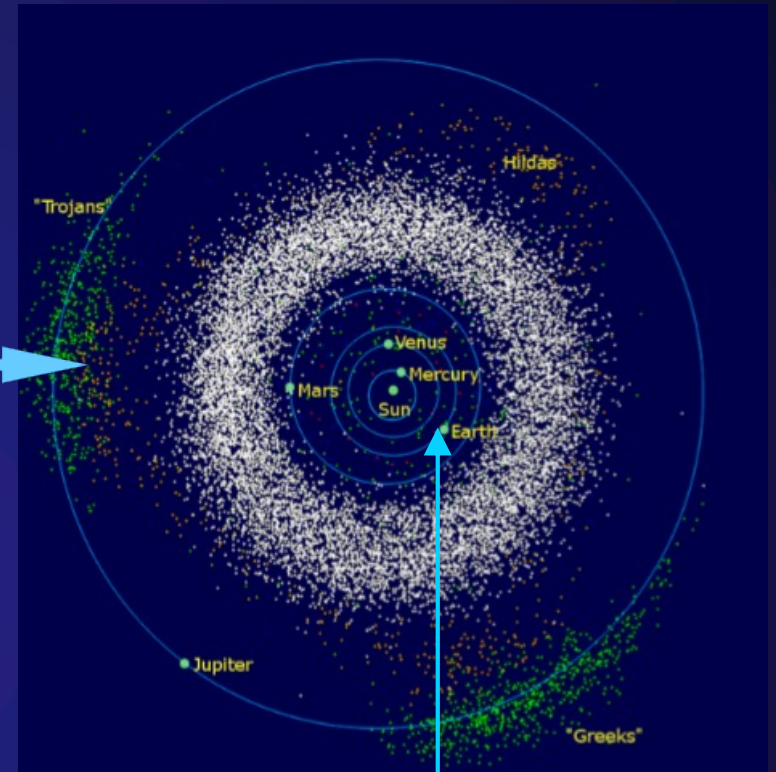
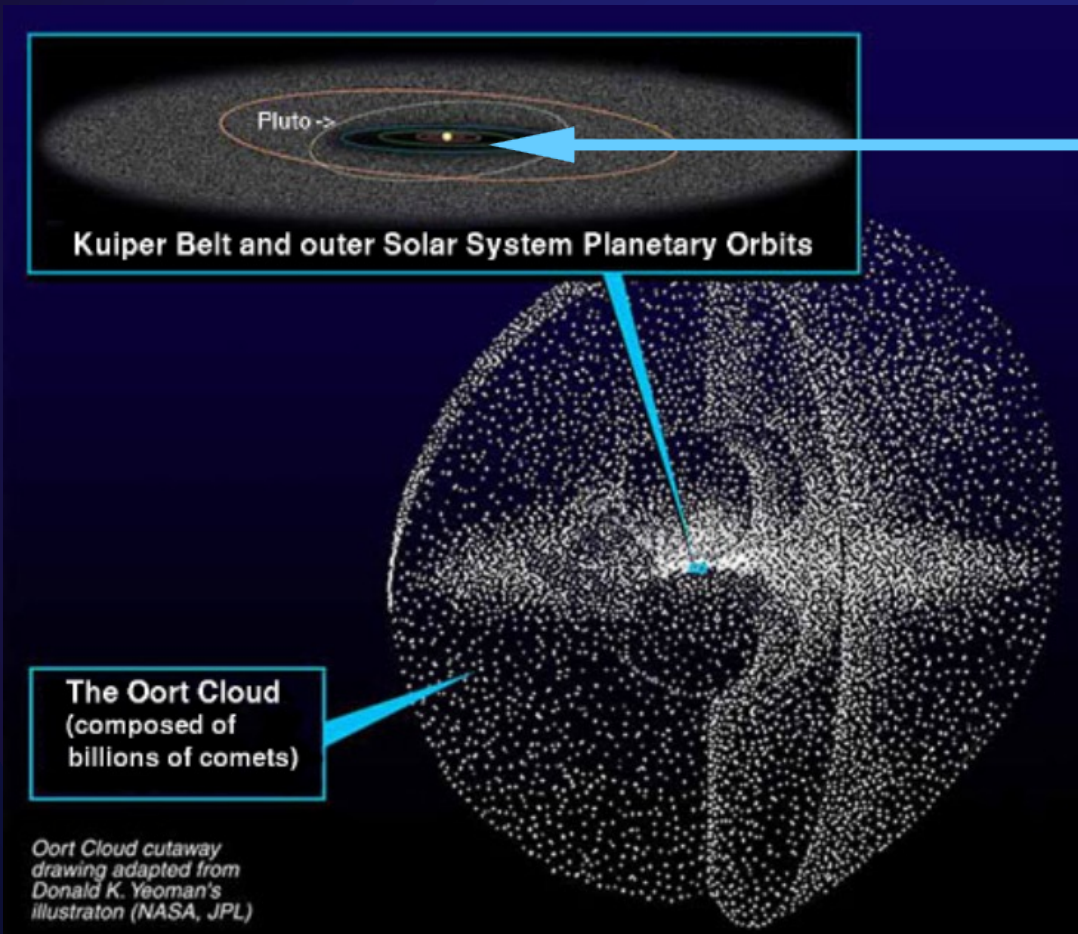
Dr. Cathy Plesko

July 21, 2021



Managed by Triad National Security, LLC for the U.S. Department of Energy's NNSA

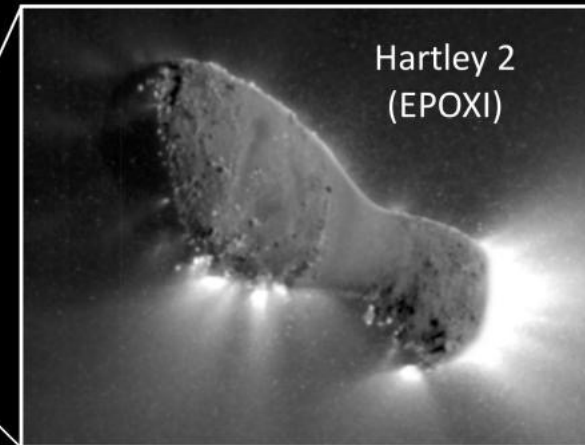
Our busy solar system



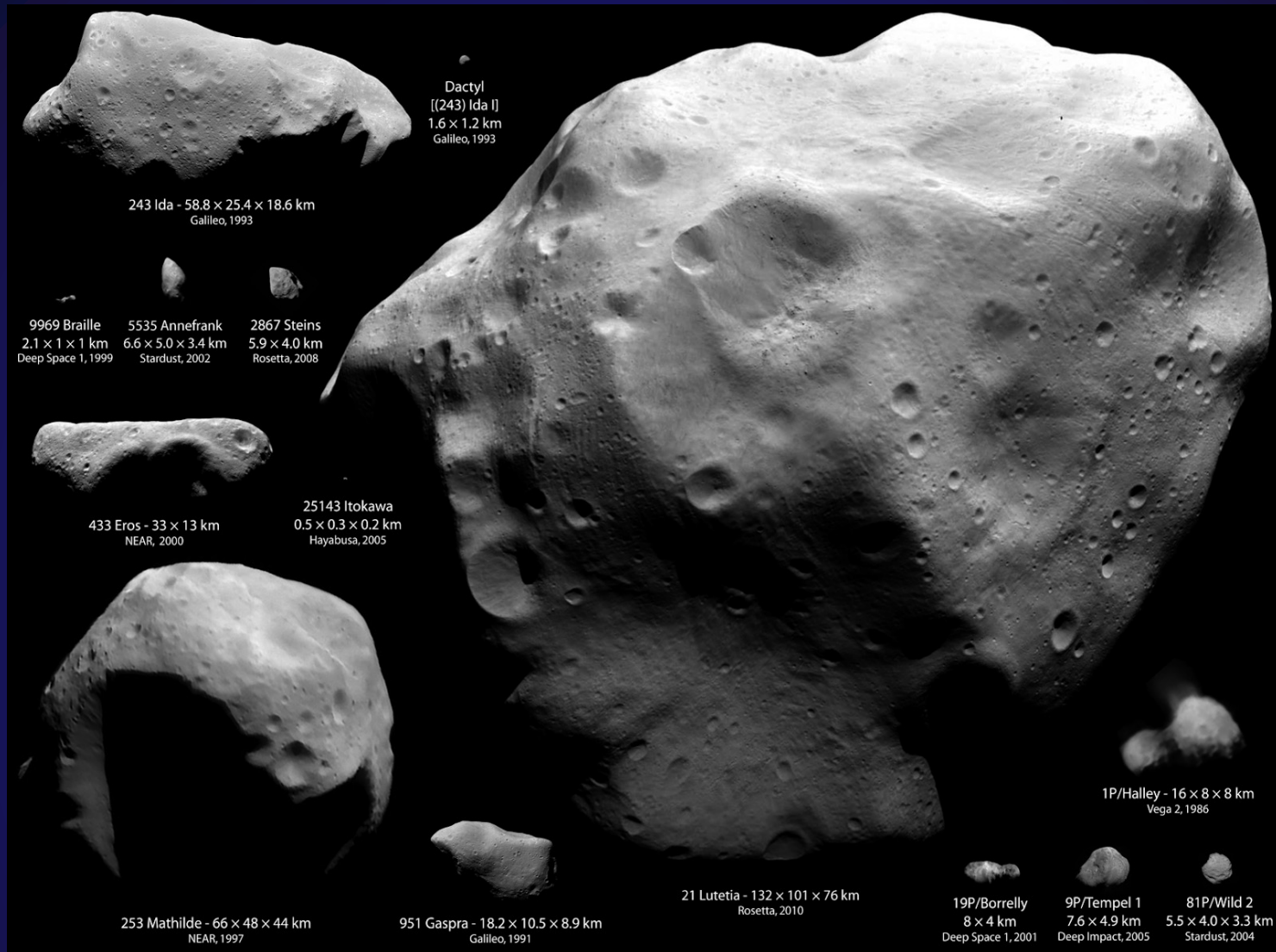
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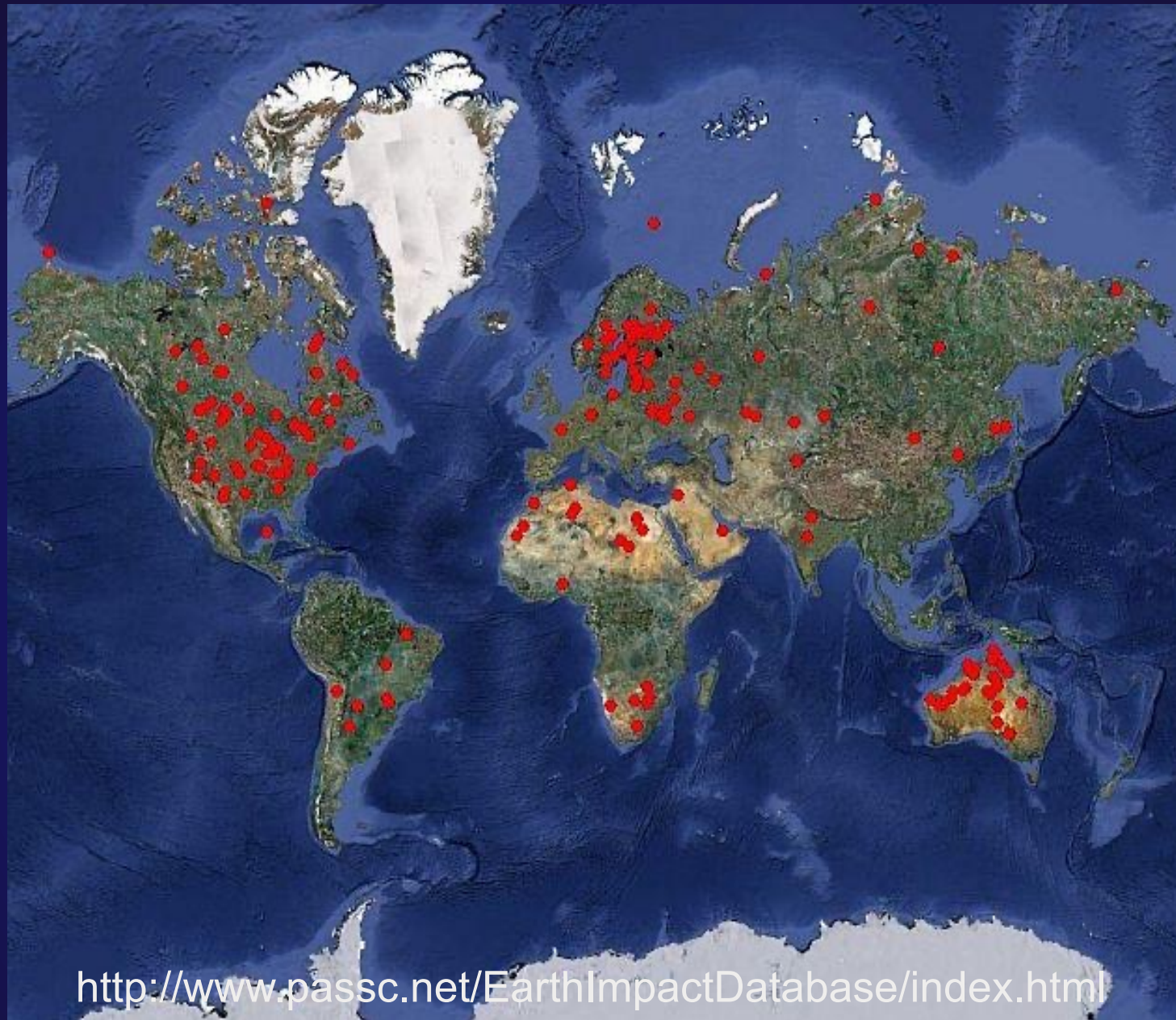
1.25 miles



Comets are more ice than rock.

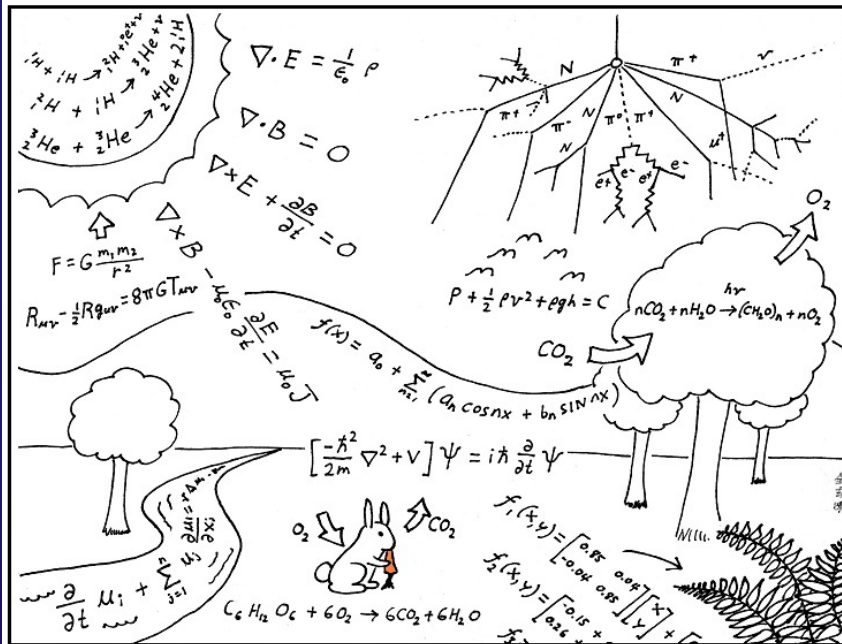
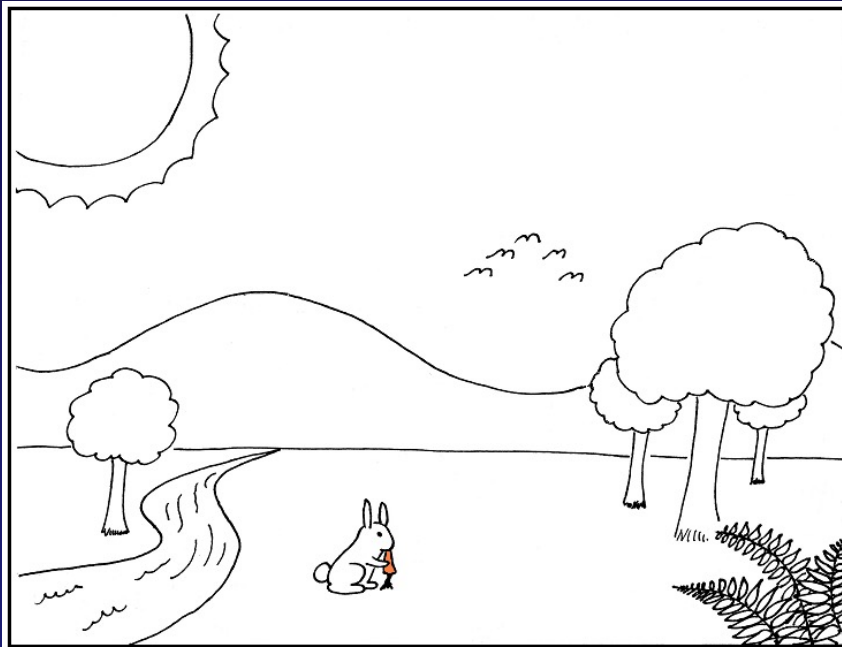


Asteroids are more rock than ice.





"All is number."
-Pythagoras



This is how scientists see the world.

Harsh truth courtesy AbstruseGoose.com

A 3D simulation of an oblique asteroid impact into water. The image shows a large, turbulent plume of water and debris being ejected from the impact site. The plume is colored with a gradient from blue at the base to yellow and green at the top, indicating temperature or energy distribution. The background is a solid blue color.

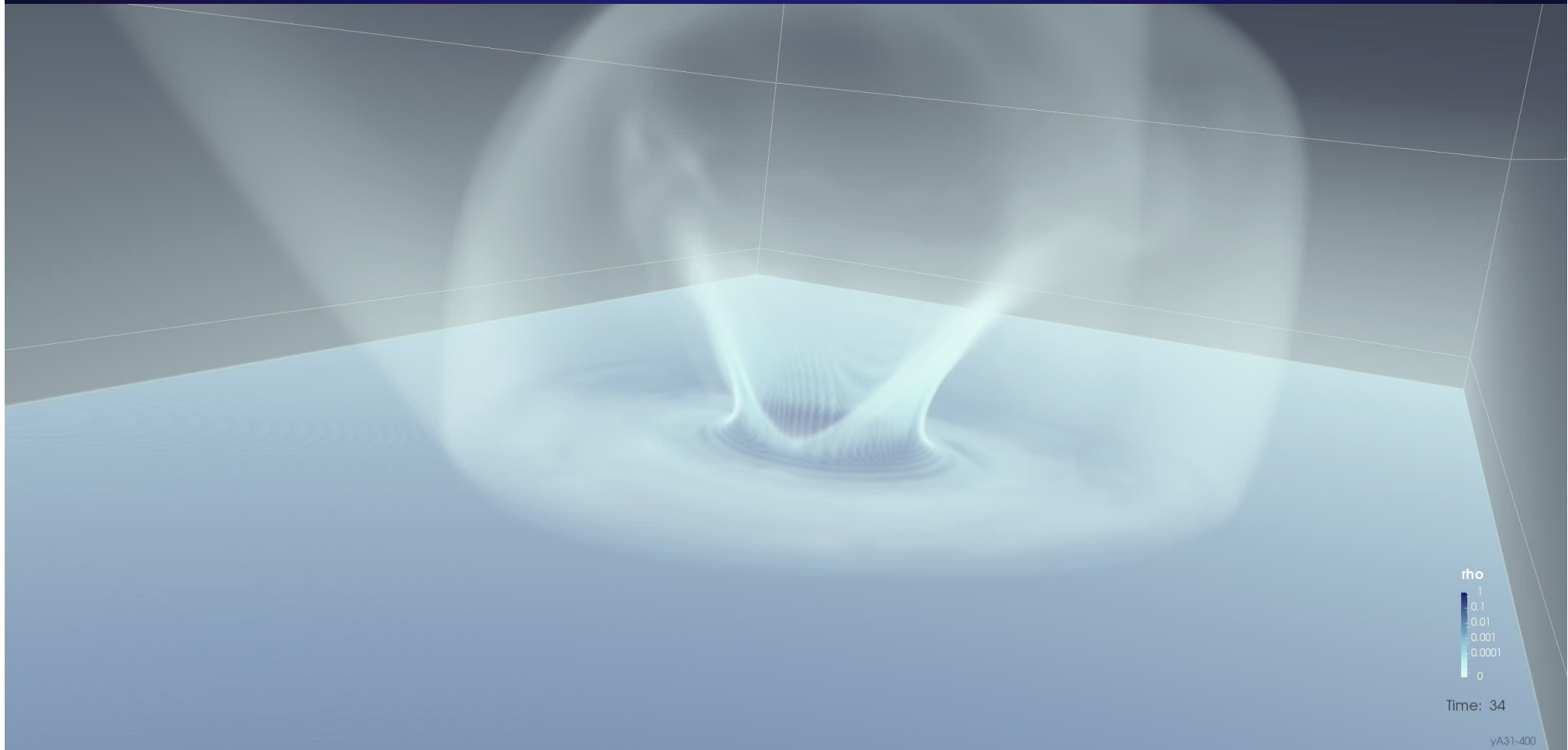
Three-dimensional simulations of oblique asteroid impacts into water

**Galen Gisler, Los Alamos National Laboratory
with T Heberling, C Plesko, R Weaver (LANL)**

Results on water impacts of small (<300 m diameter) asteroids

- Impacts or airbursts near populated shores are dangerous.
- Impacts far from shore are spectacular and may produce detectable waves at great distances.
- Airbursts over water are less effective at generating waves than impacts into water.
- The most significant effect of an impact into an ocean is the injection of water vapor into the stratosphere, possibly affecting climate.

Impact of a 250-meter diameter asteroid into a deep ocean



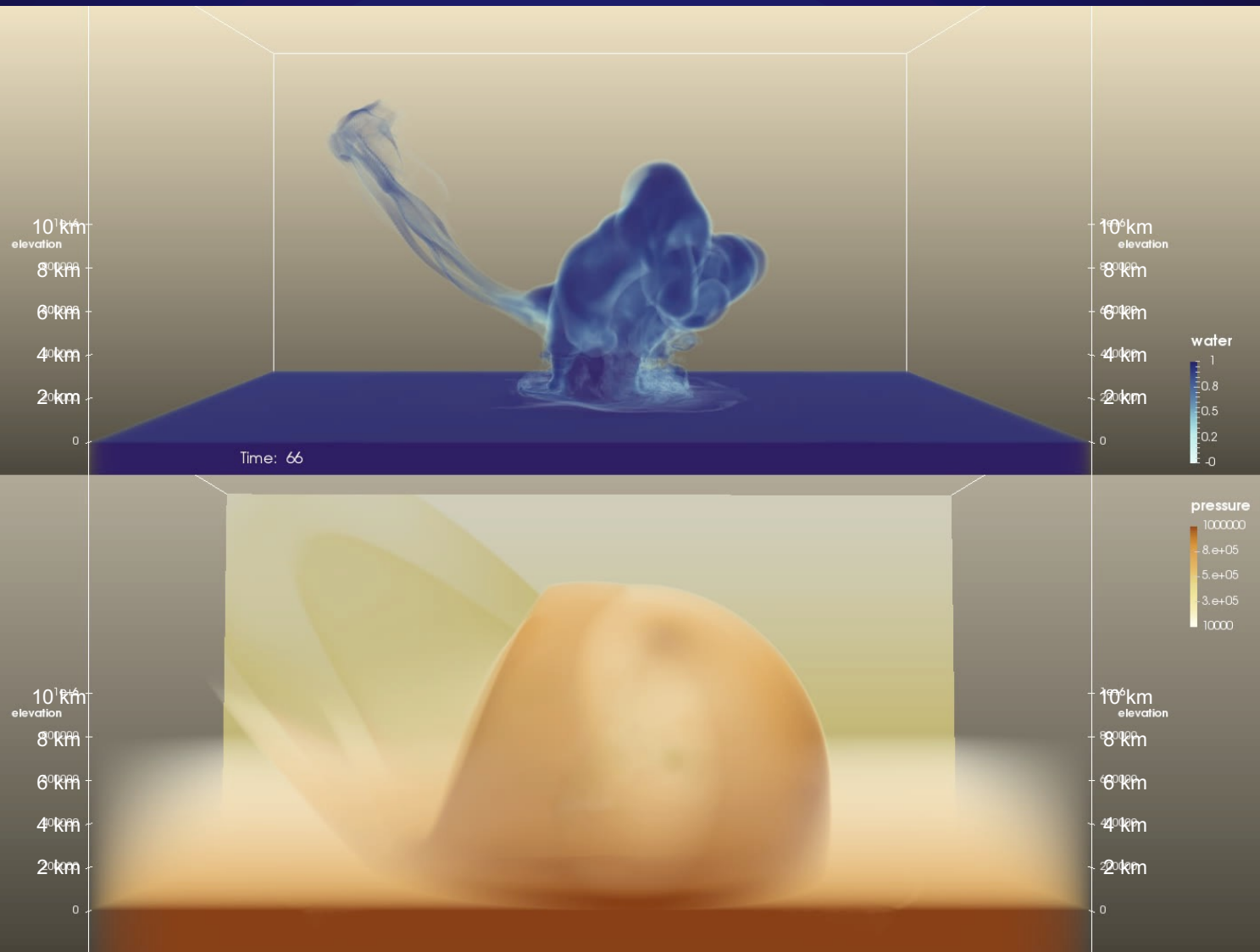
Volume rendering of density.

Visualizations in this presentation were made by a team at Los Alamos (John M. Patchett, David H. Rogers, Boonthanome Nouanesengsy) and University of Texas (Francesca G. Samsel, Karen Tsai, Gregory D. Abram, Terece L. Turton) using simulation data generated by Galen Gisler.

You don't want to be close to an impact site!



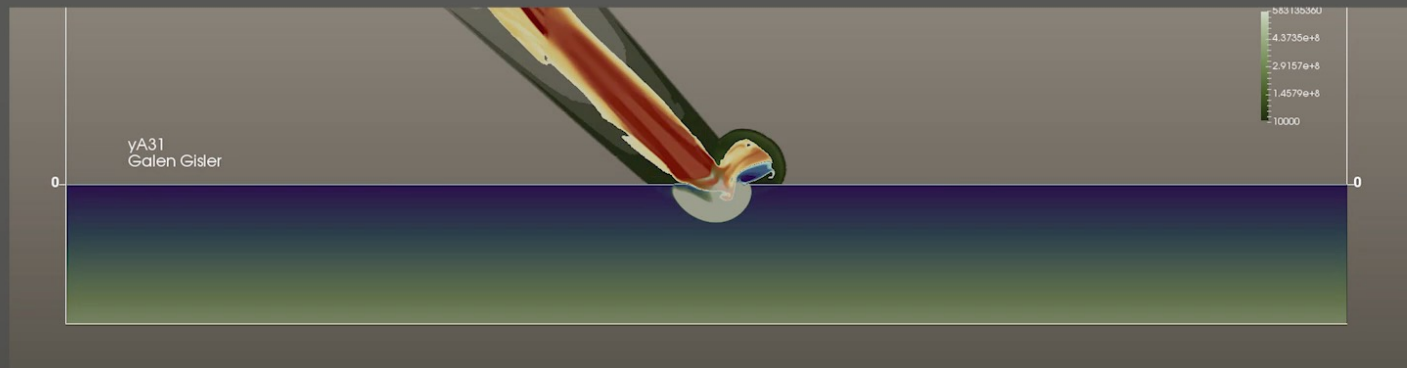
250 m asteroid, no airburst, 45° trajectory



Volume rendering of water mass fraction (top) and pressure (bottom)

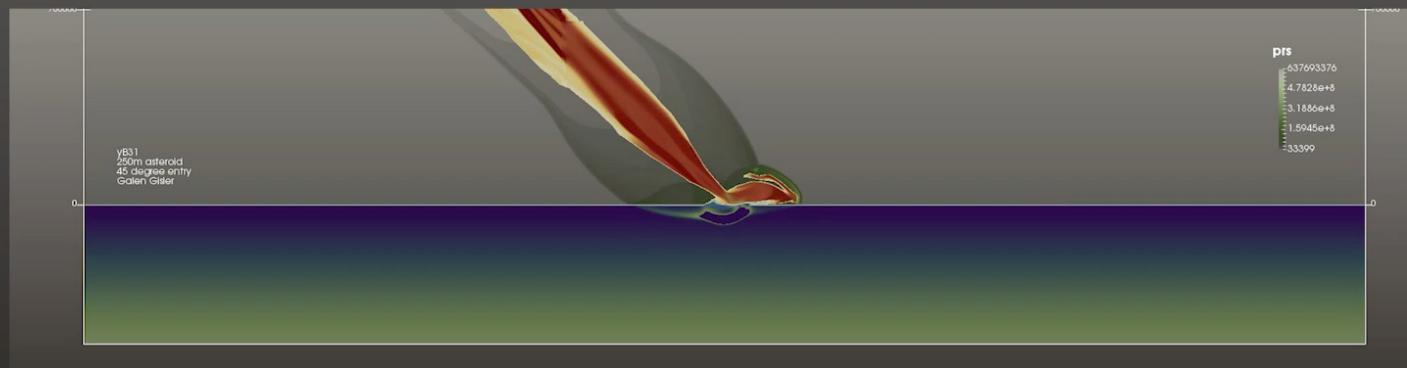
Direct comparison of 3 calculations showing pressure (green),
asteroid mass fraction (red), water mass fraction (blue)

yA31



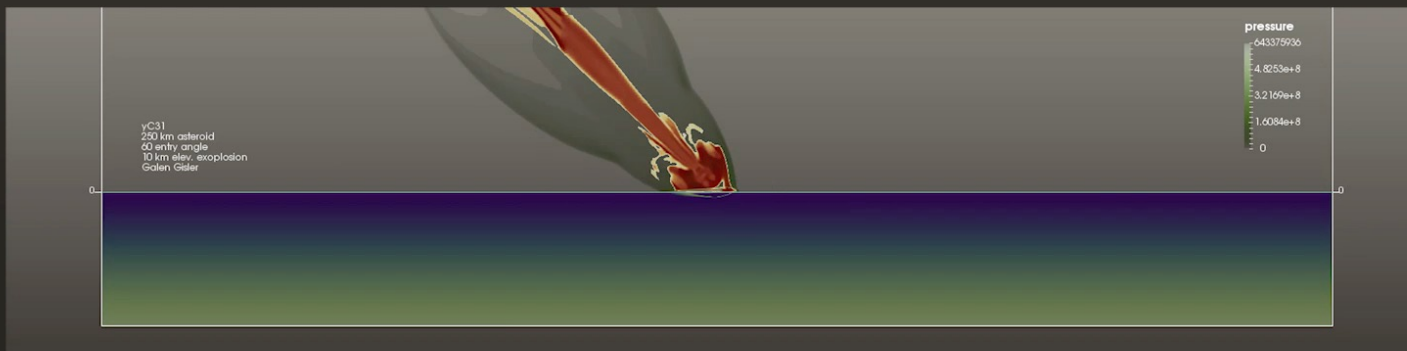
No
Airburst

yB31



Airburst
at 5km

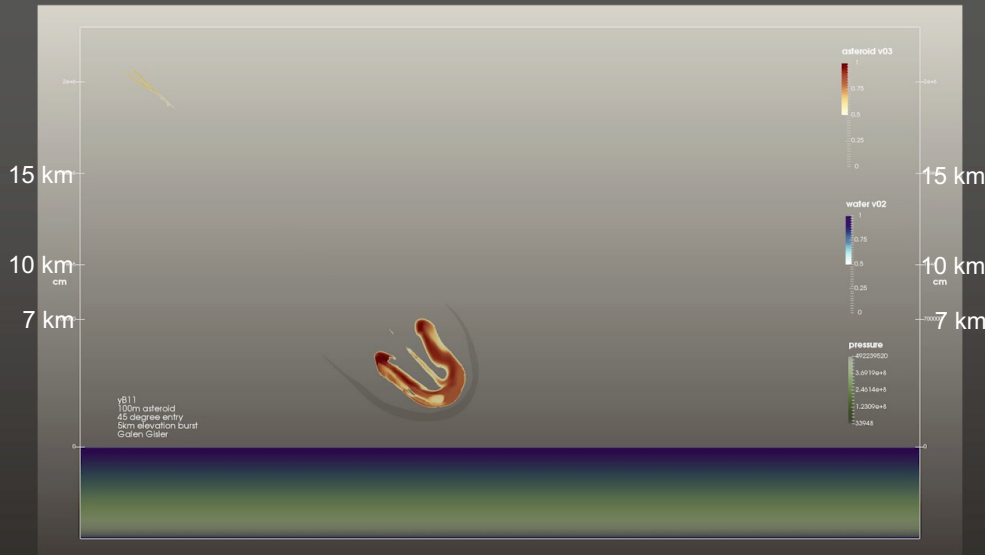
yC31



Airburst
at 10km

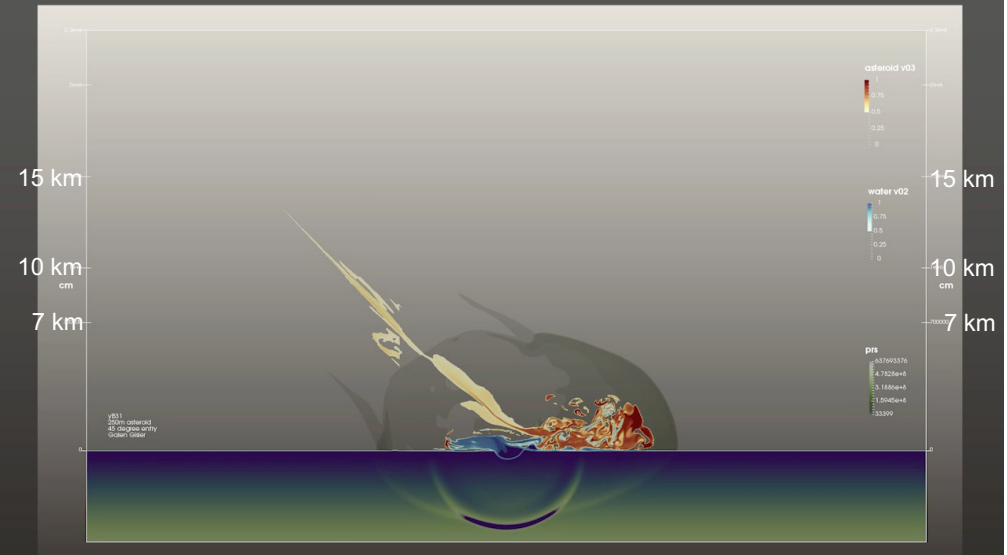
Calculations of different sized impactors

yB11



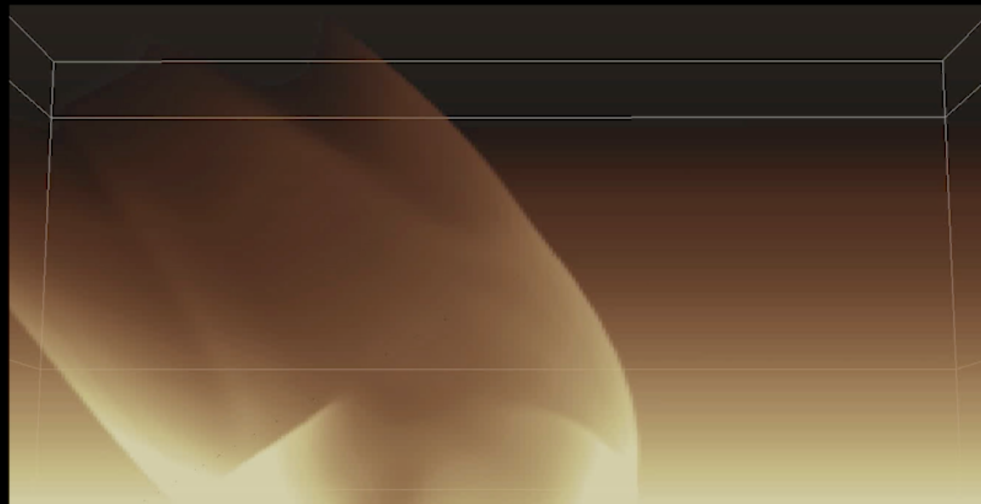
100m Diameter

yB31

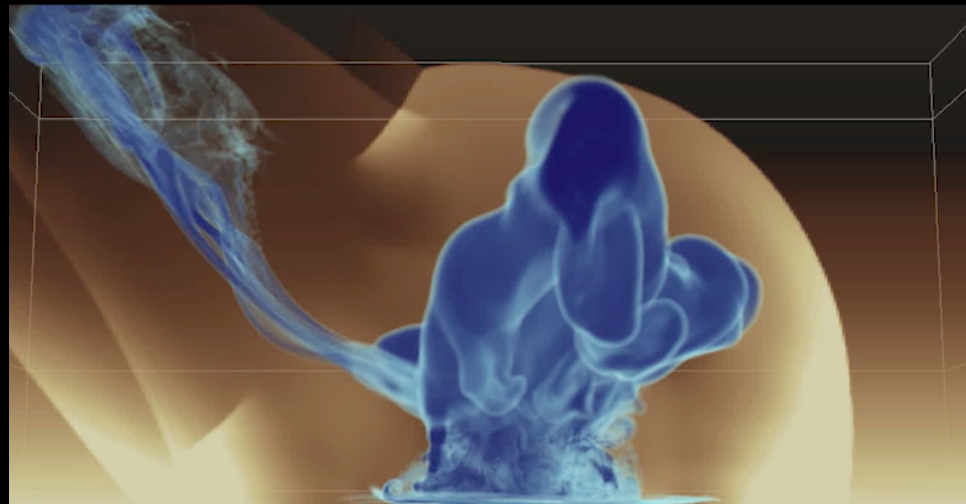


250m Diameter

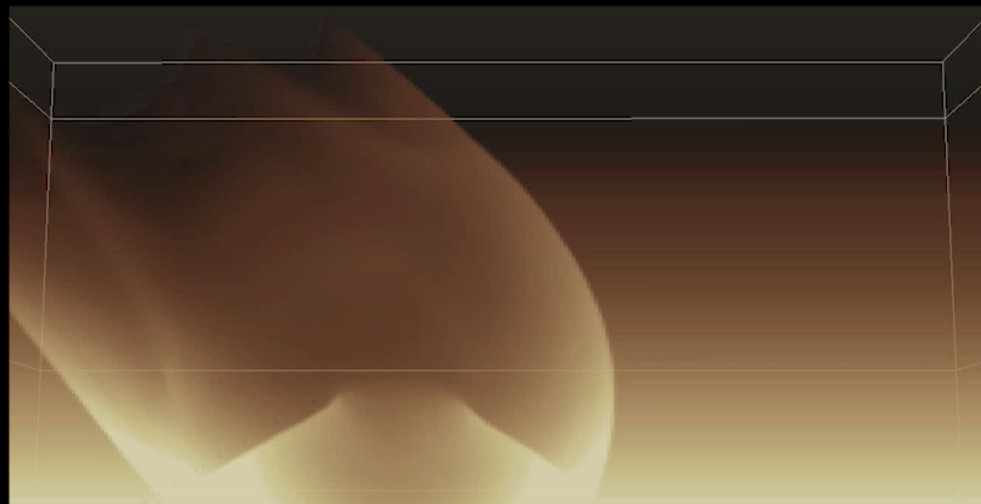
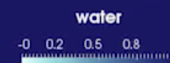
Airburst at 5km
45° Impact Angle



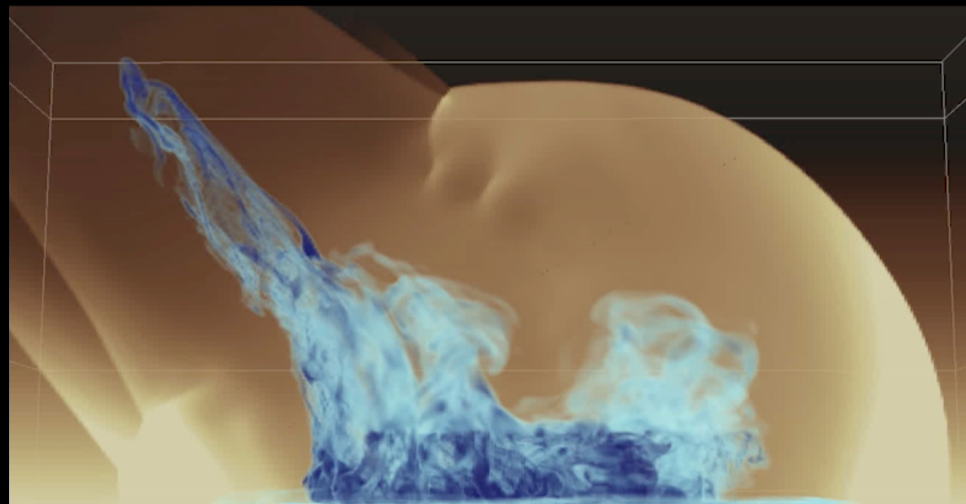
100 meter asteroid
no airburst



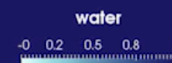
250 meter asteroid
no airburst



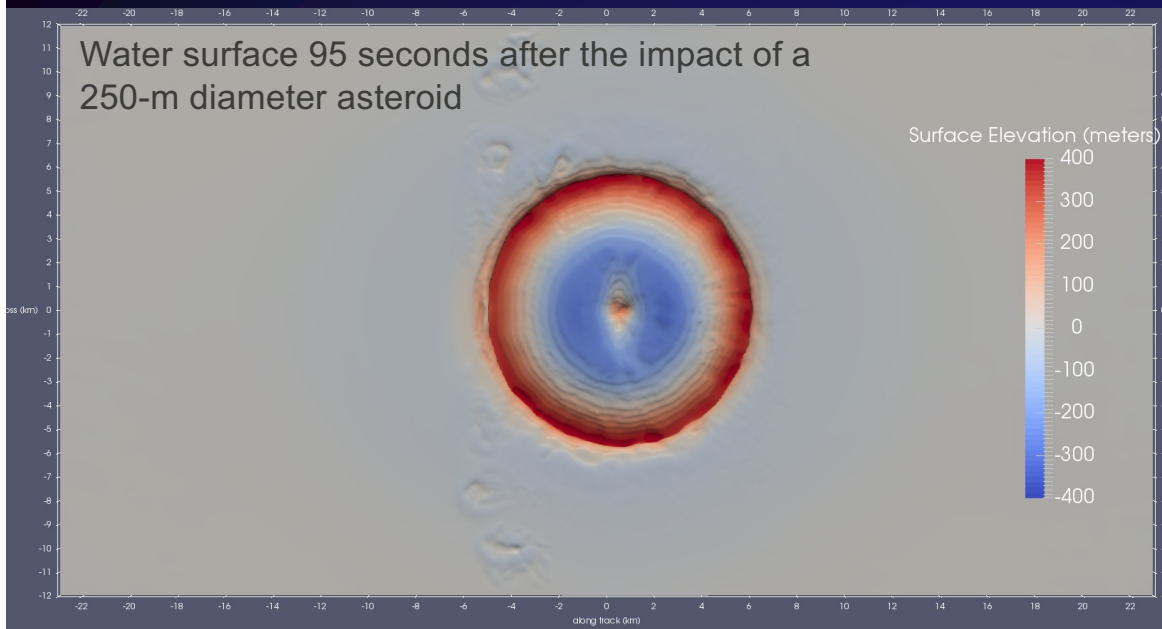
100 meter asteroid
5 km airburst



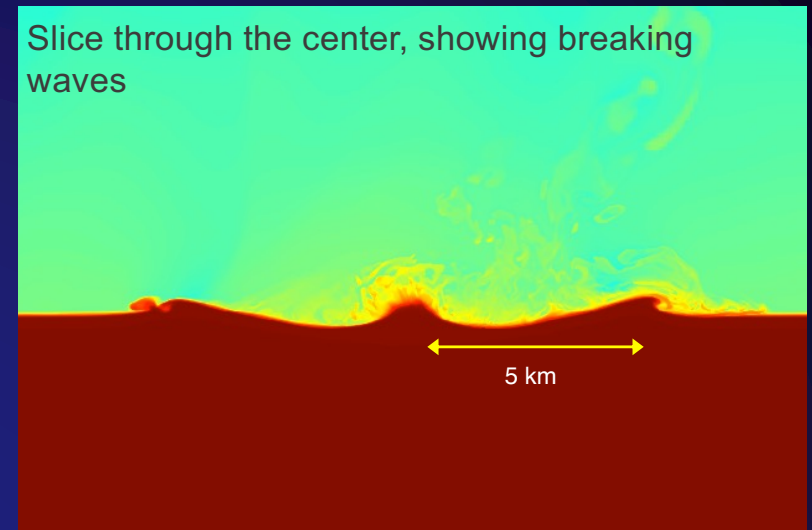
250meter asteroid
5 km airburst



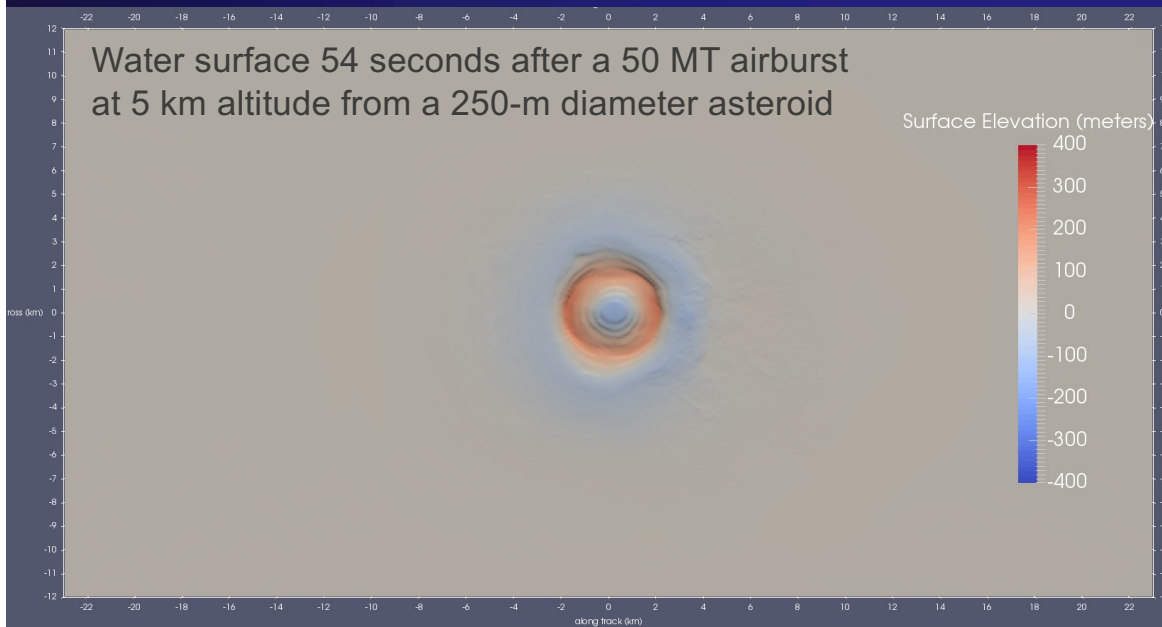
Water surface 95 seconds after the impact of a 250-m diameter asteroid



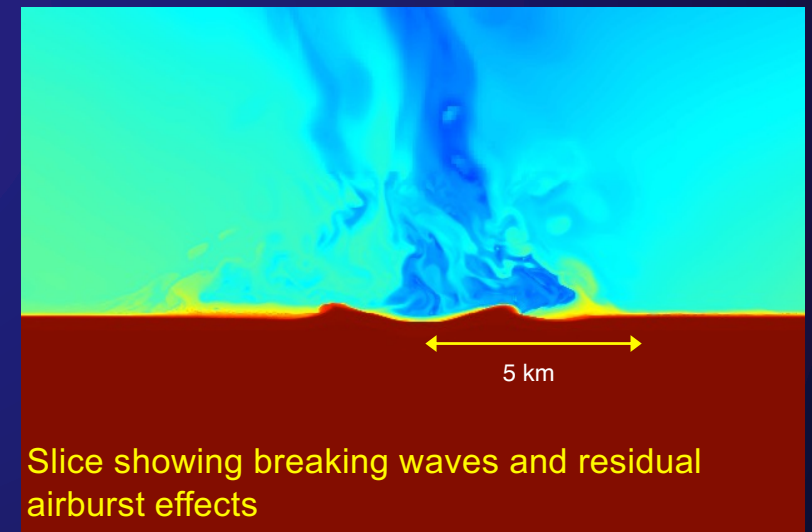
Slice through the center, showing breaking waves



Water surface 54 seconds after a 50 MT airburst at 5 km altitude from a 250-m diameter asteroid



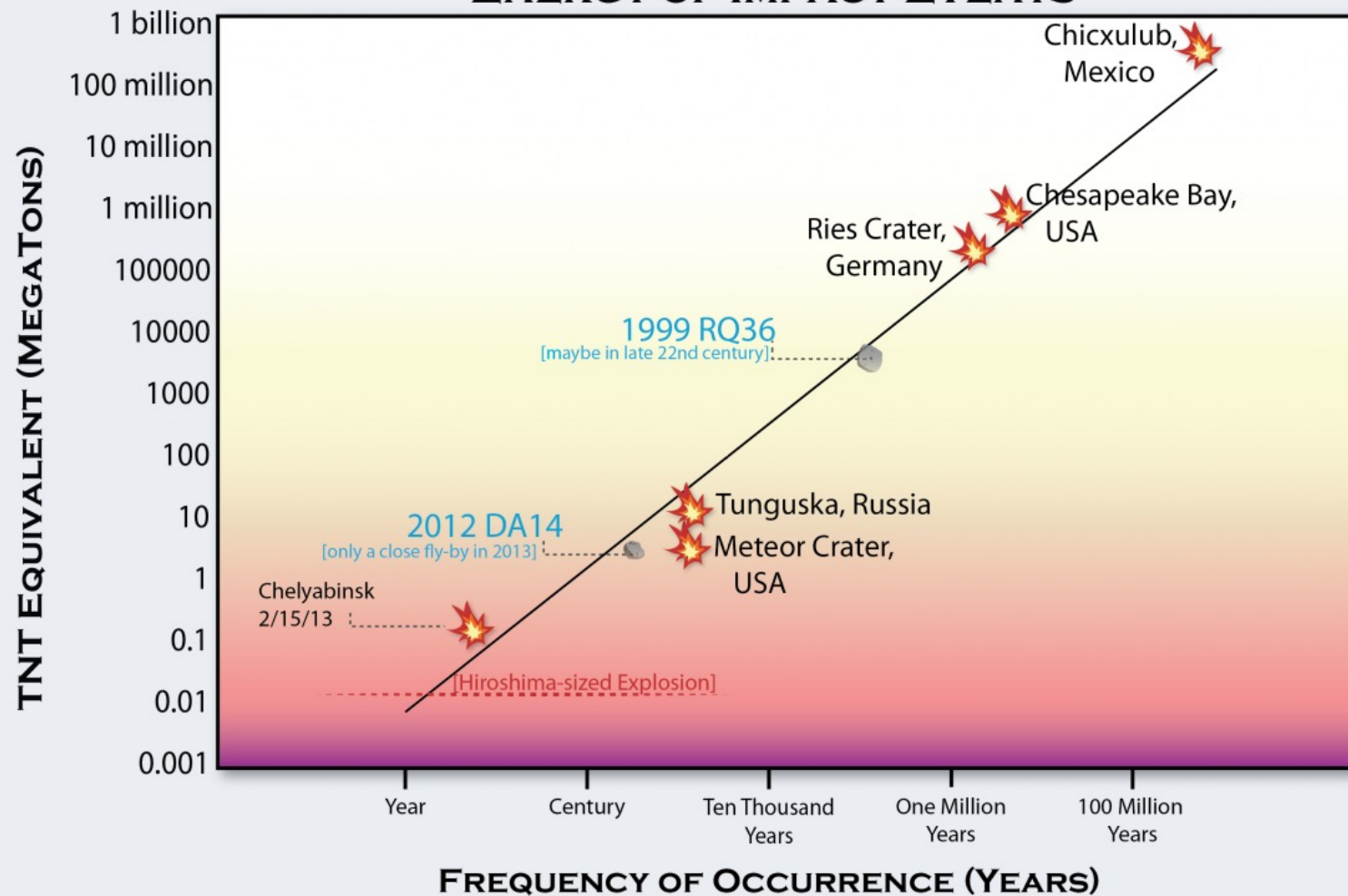
Slice showing breaking waves and residual airburst effects



The wavelength of these surface waves is much smaller than typical tsunami wavelengths. They are therefore not expected to propagate efficiently over long distances.

ROCKS FROM SPACE

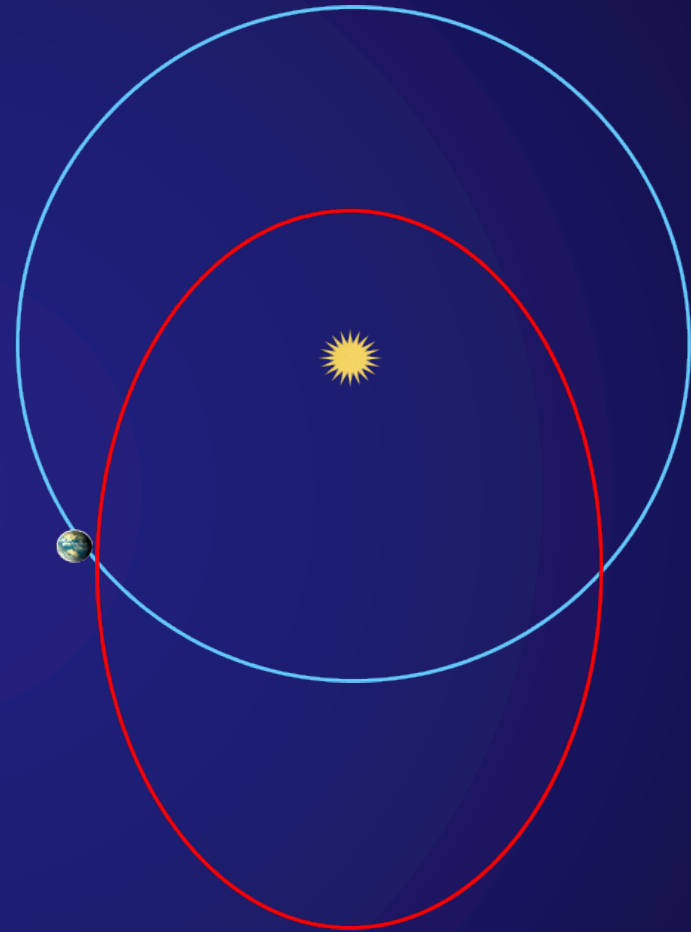
ENERGY OF IMPACT EVENTS



Plot courtesy NASA/OsirisREX

Impact Prevention: Deflection

- **Push to alter orbit**
- **Mechanisms:**
 - kinetic
 - explosive
 - light
 - gravity
 - rockets
- **Diameter > 100 m**
- **Reaction time \sim years to decades**

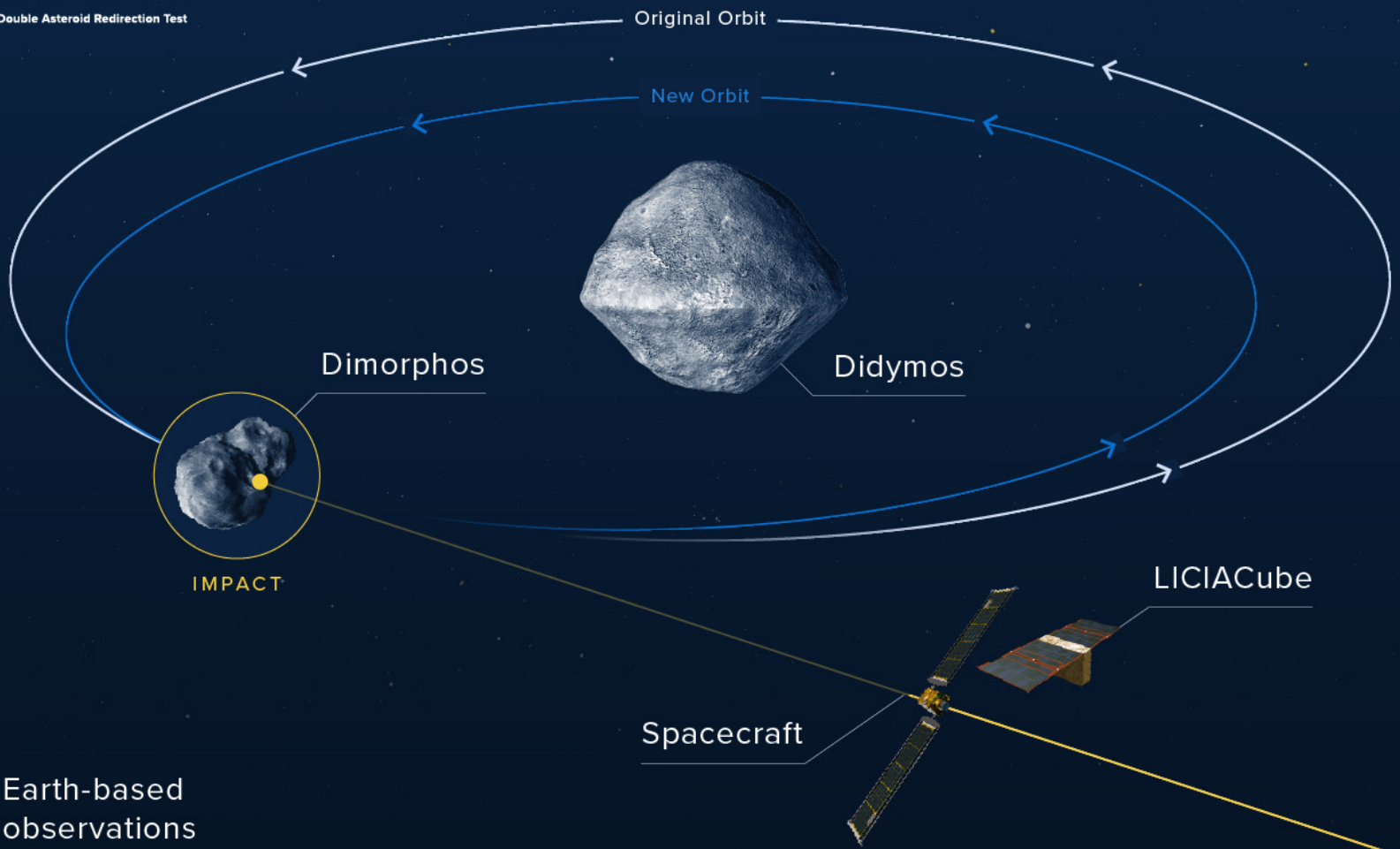


Preventing Impacts: Disrupt and Disperse

- **Fragment**
- **Scatter fragments**
- **Mechanisms:**
 - kinetic
 - explosive
 - mechanical
- **Works best for:**
 - Shorter warning
 - Smaller objects



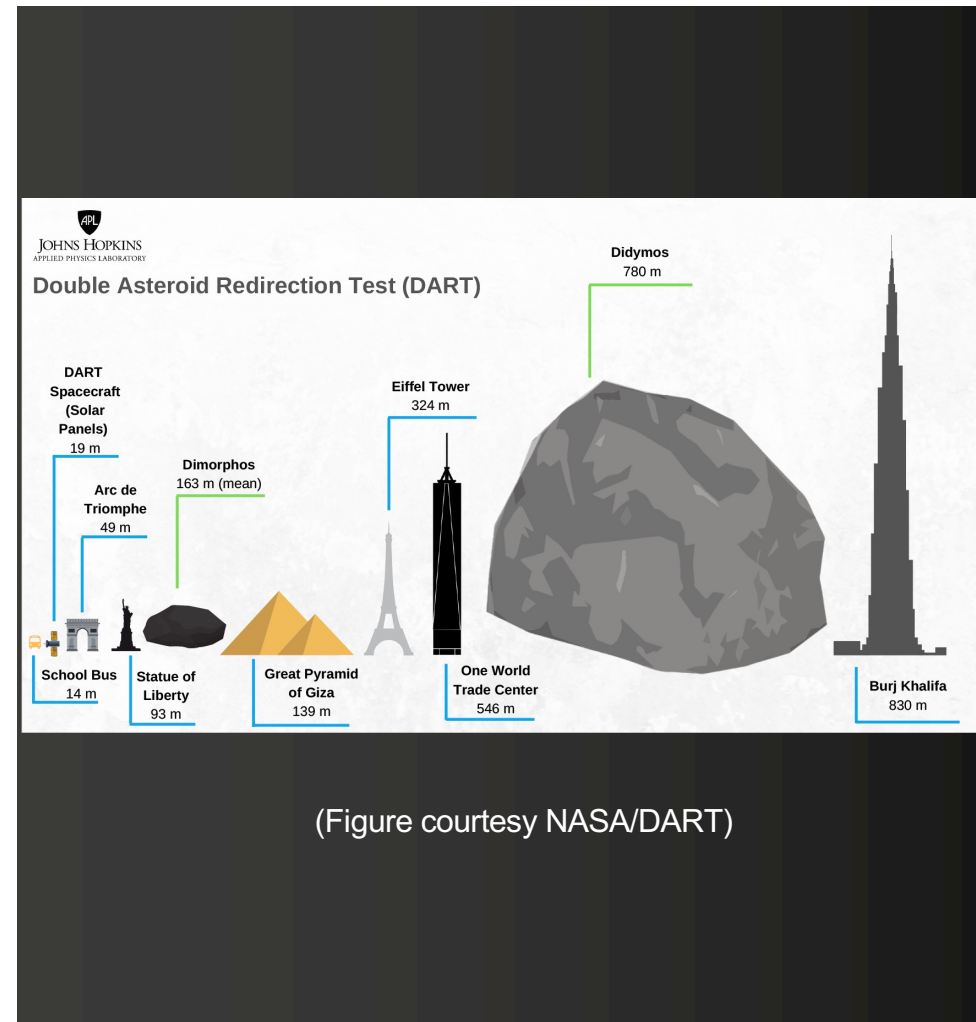
NASA: Deep Impact Mission



We can test the physics with an experiment

The Target: Asteroid Dimorphos

- Target of the DART kinetic impactor mission
- Smaller member of a binary system
- 100-m-diameter, rocky mixed-type asteroid, 25% porosity
- Tunguska Meteor-sized
- Modeled 4 kinetic impactor scenarios

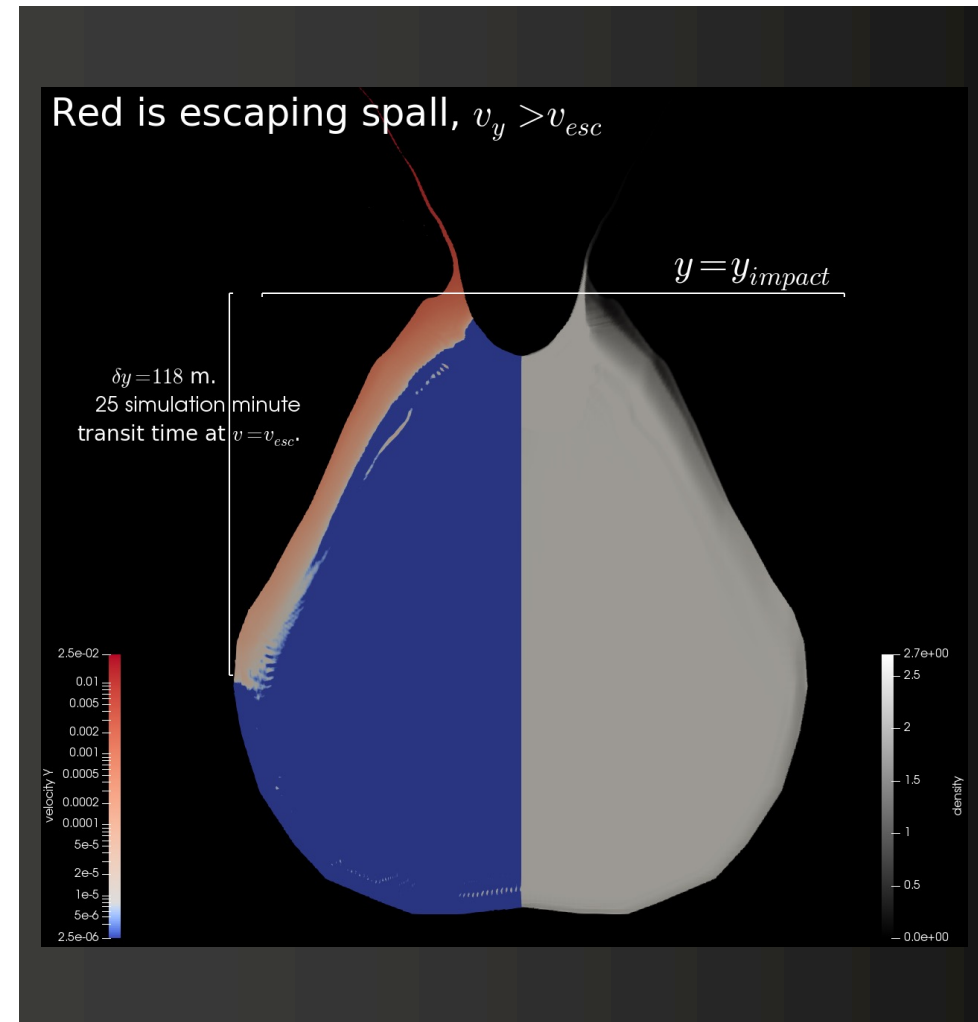


Model	Impactor Mass [kg]	Impactor Velocity [km/s]	Impact Angle [°]
1	10350.4	19.75	0
2	10350.4	19.75	90
3	7897.0	8.1	0
4	7897.0	8.1	90

Computer Model Results

- NASA designed trajectories assuming a perfectly inelastic collision (100% momentum transfer efficiency)
- We estimate 400-2000% momentum transfer efficiency
- Total *system* momentum is conserved
- Spall, shrapnel mean *target mass is not constant*
- So remaining target can have a higher momentum.

Model	m_i [kg]	v_i [km/s]	θ_i [°]	m_{ej} [kg]	β	Δv [cm/s]
1	10350.4	19.75	0	$> 6.7 \times 10^7$	> 7	> 30
2	10350.4	19.75	90	$> 1.2 \times 10^9$	> 17	> 100
3	7897.0	8.1	0	8.2×10^8	21	36
4	7897.0	8.1	90	1.3×10^8	20	38

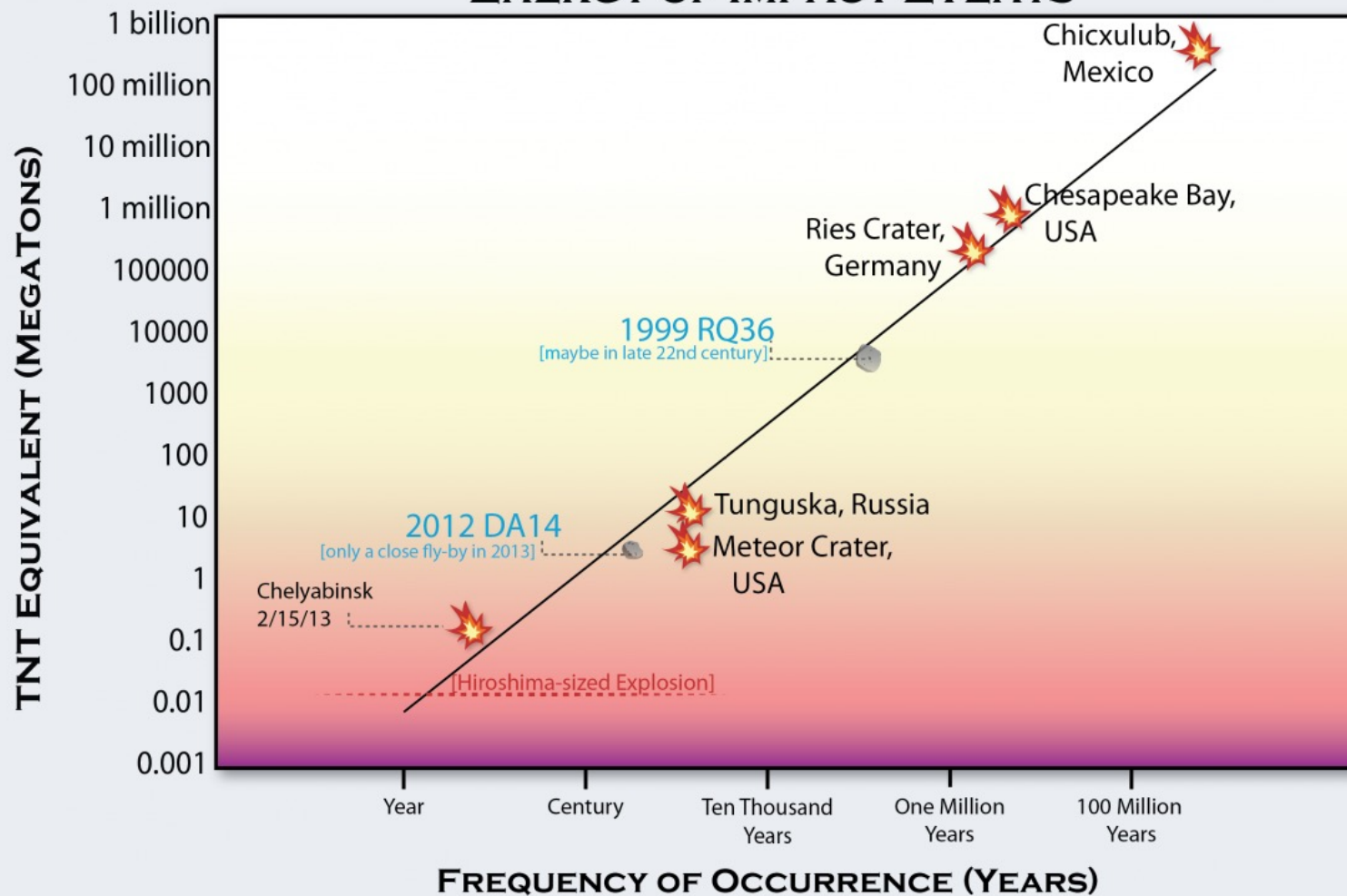


Questions?

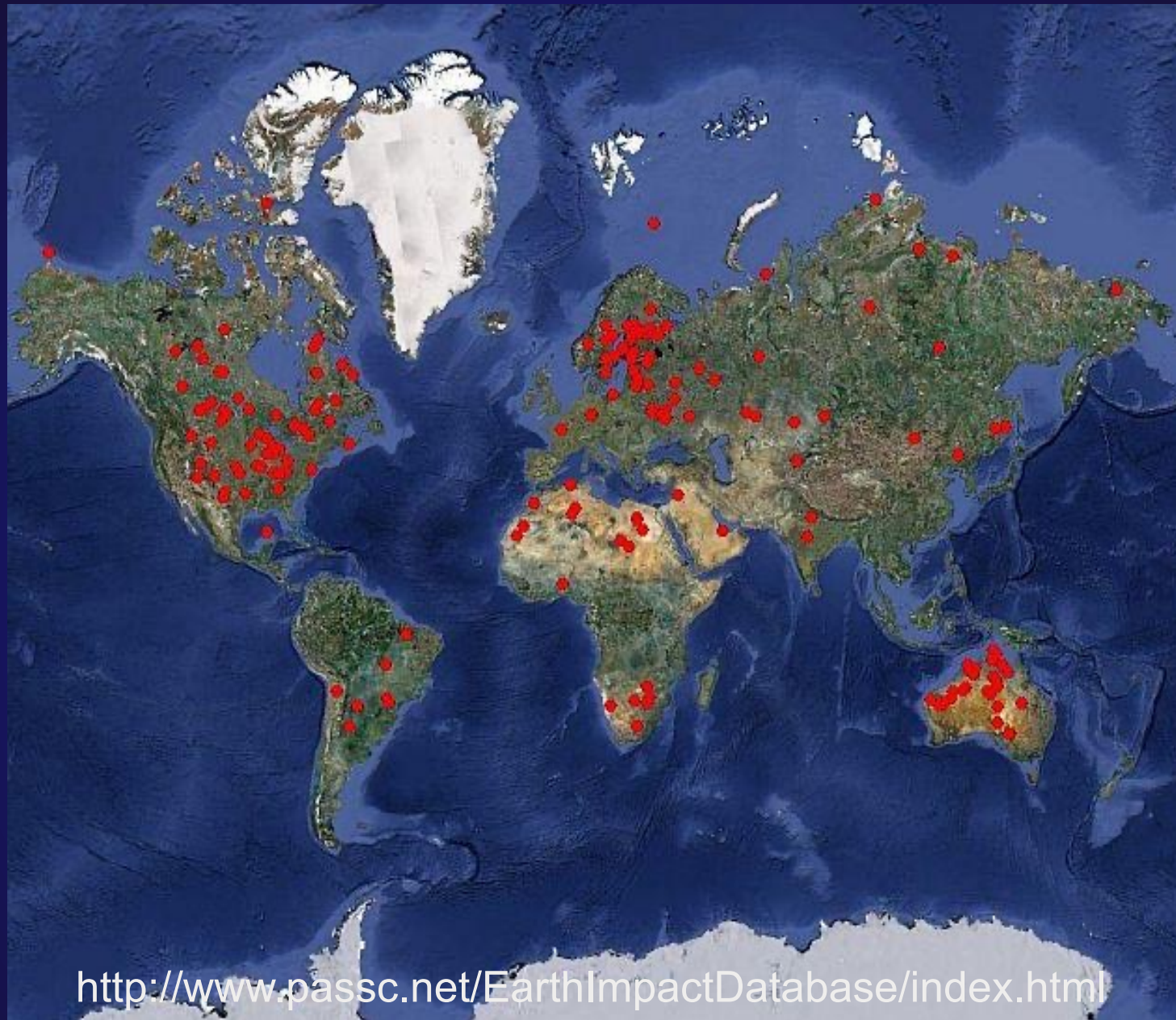
**How often do impacts happen,
and how do we know that,
exactly?**

ROCKS FROM SPACE

ENERGY OF IMPACT EVENTS



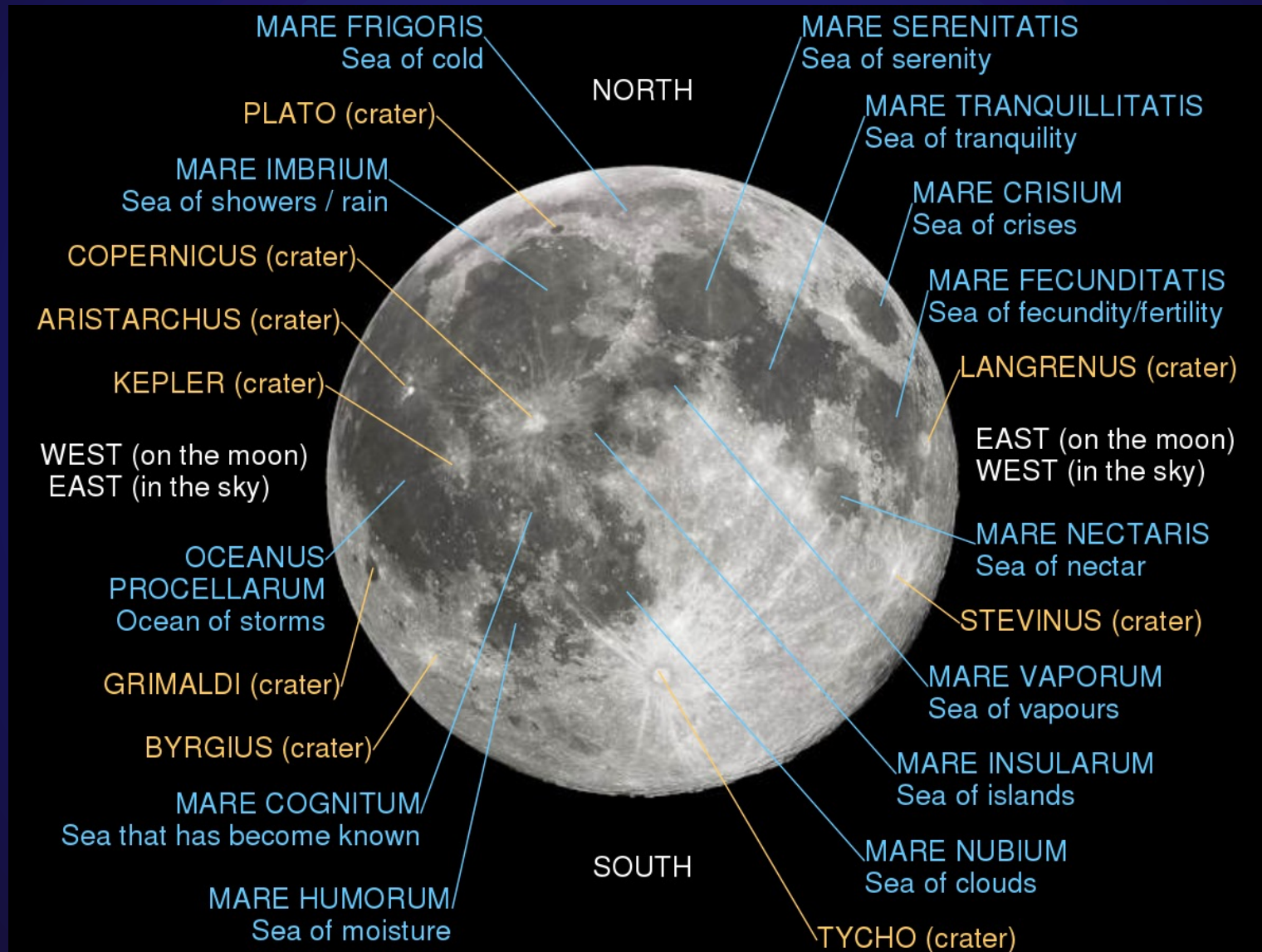
Plot courtesy NASA/OsirisREX



The Moon: No plate tectonics or liquid water.



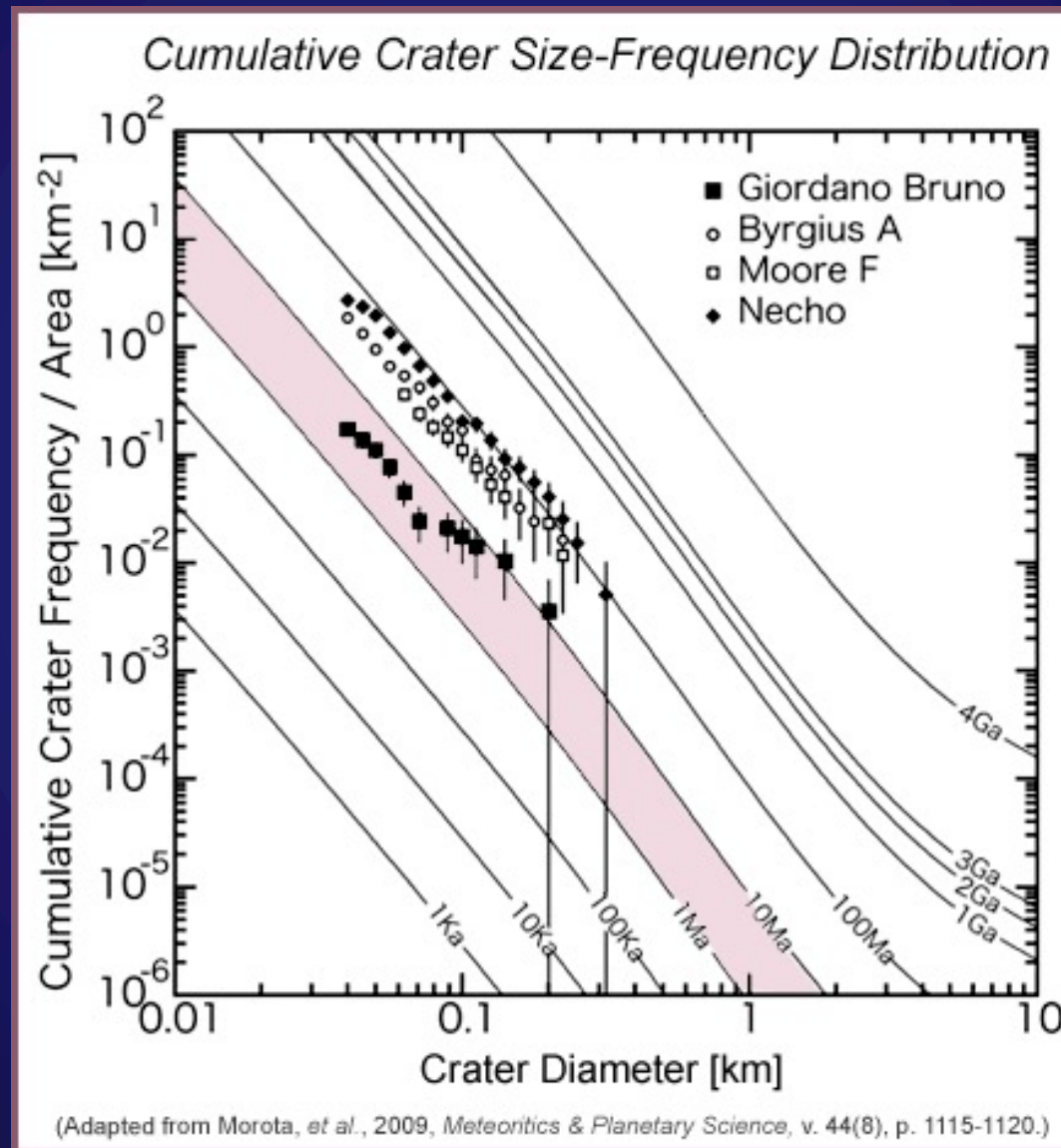
Scientists count the craters



The age of rocks collected on the Moon were estimated from radioactive decay of the minerals.



Then we know how many there are of a given size, and how old they are.

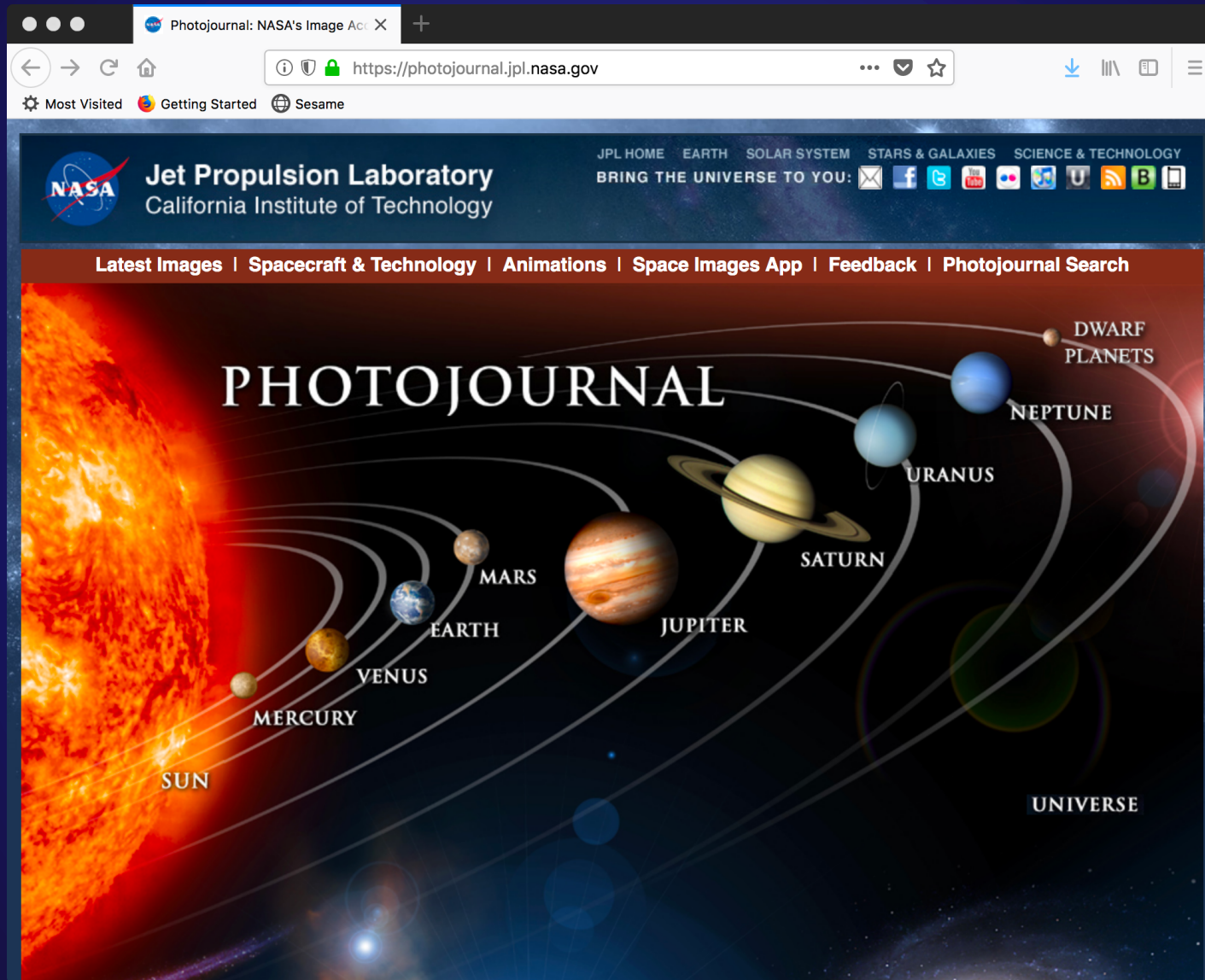


If you know that, you can estimate how often objects of a given size hit the Moon (and the Earth).

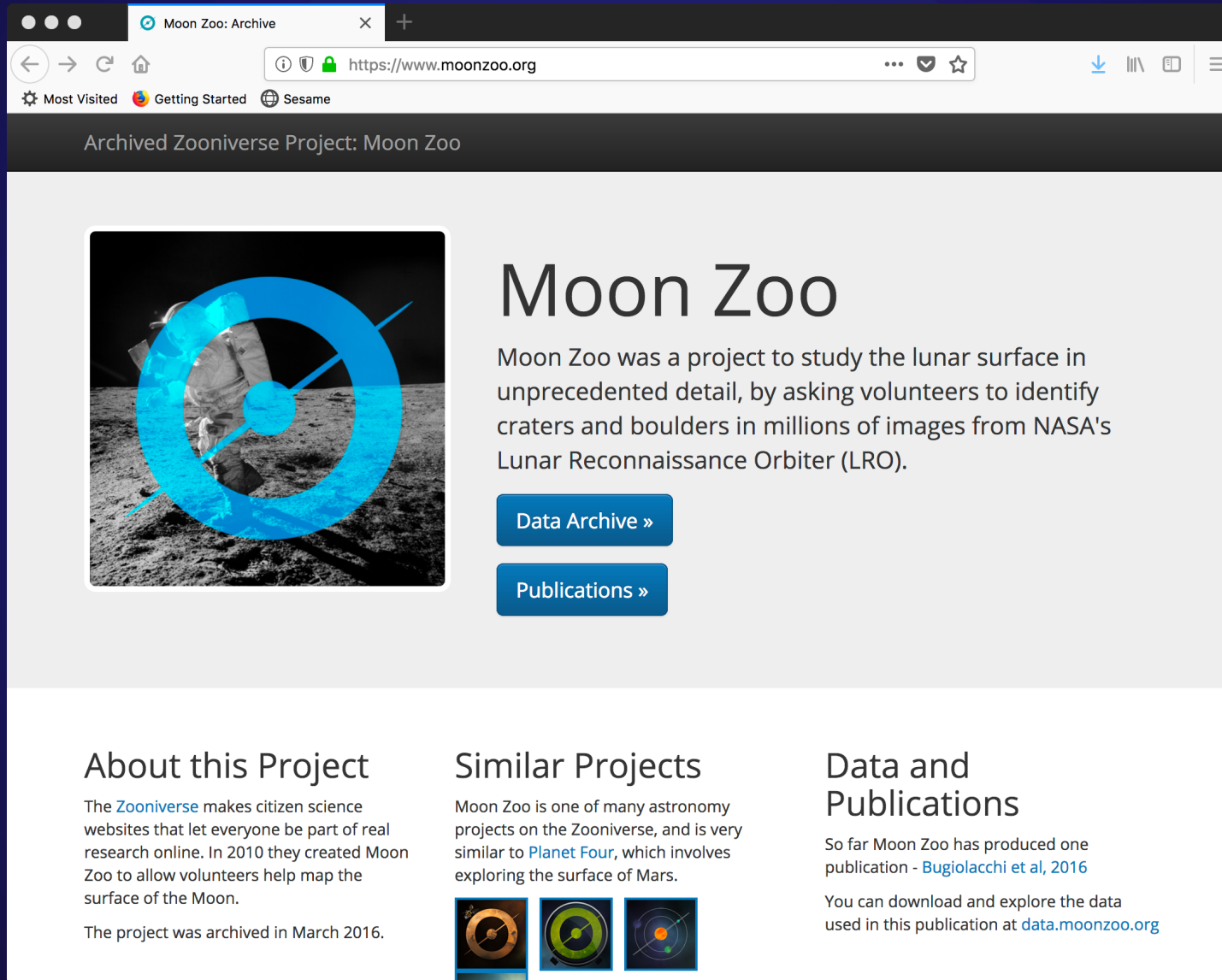
But...

This is a detailed map of the North Polar region of Mars, showing various craters, geographical features, and names of scientists and explorers. The map is circular, with latitude and longitude lines marked. Key features include the Tharsis volcanic plateau, the Valles Marineris, and the deep impact craters. Numerous craters are labeled with names such as Birkhoff, Emden, Tikhov, and others. The map also shows the Martian atmosphere and the surrounding space.

Fortunately, there's plenty of data




Some projects use crowdsourcing



The screenshot shows a web browser window with the address bar displaying "https://www.moonzoo.org". The page title is "Moon Zoo: Archive". The main heading is "Moon Zoo". Below the heading is a paragraph describing the project: "Moon Zoo was a project to study the lunar surface in unprecedented detail, by asking volunteers to identify craters and boulders in millions of images from NASA's Lunar Reconnaissance Orbiter (LRO)." There are two buttons: "Data Archive »" and "Publications »". Below this, there are three sections: "About this Project", "Similar Projects", and "Data and Publications".

Archived Zooniverse Project: Moon Zoo



Moon Zoo

Moon Zoo was a project to study the lunar surface in unprecedented detail, by asking volunteers to identify craters and boulders in millions of images from NASA's Lunar Reconnaissance Orbiter (LRO).

[Data Archive »](#)

[Publications »](#)


About this Project

The [Zooniverse](#) makes citizen science websites that let everyone be part of real research online. In 2010 they created Moon Zoo to allow volunteers help map the surface of the Moon.

The project was archived in March 2016.

Similar Projects

Moon Zoo is one of many astronomy projects on the Zooniverse, and is very similar to [Planet Four](#), which involves exploring the surface of Mars.



Data and Publications

So far Moon Zoo has produced one publication - [Bugiolacchi et al, 2016](#)

You can download and explore the data used in this publication at data.moonzoo.org

Some projects use machine learning

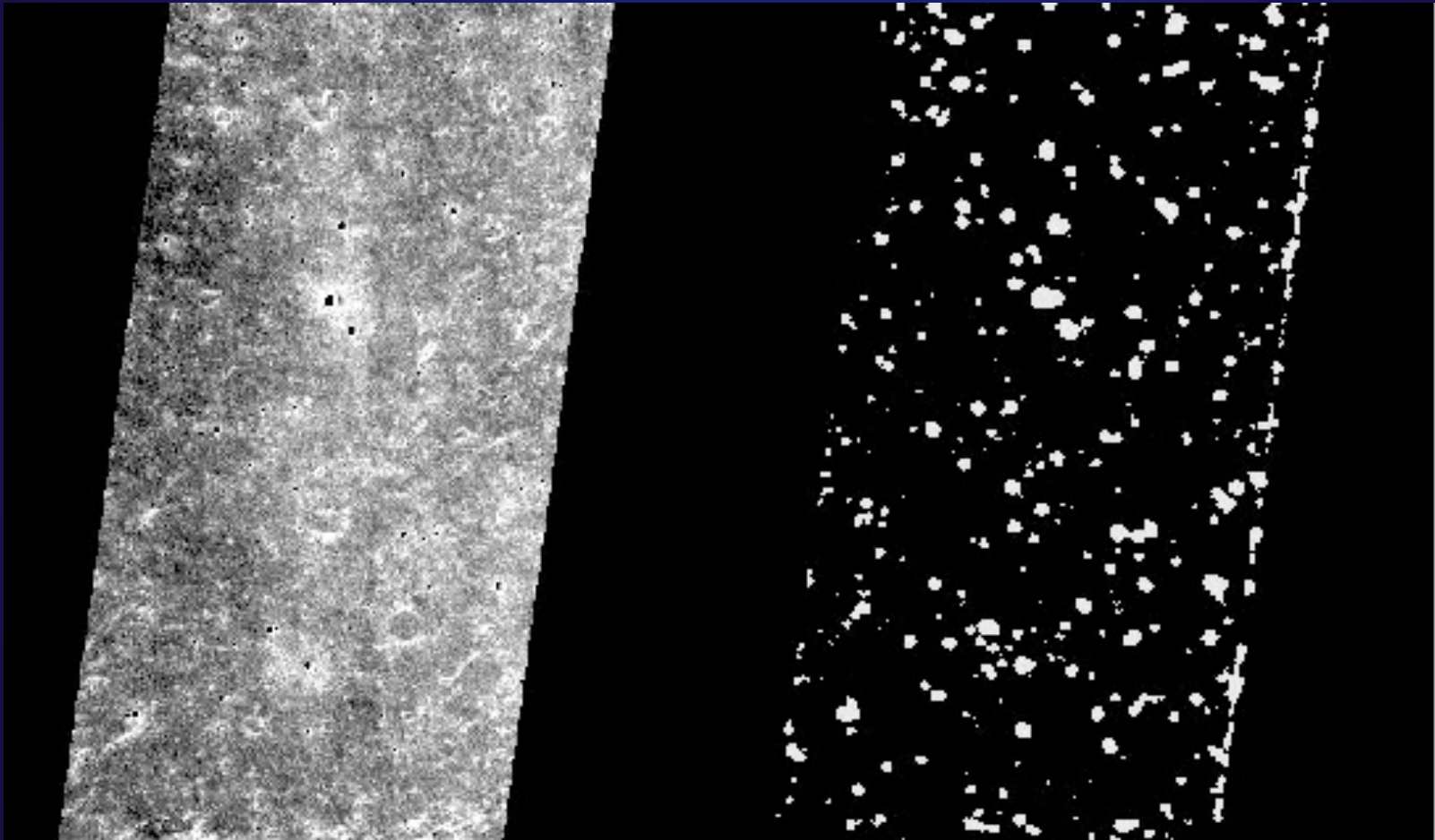


Figure 2. MOC Image M0803054: Test Scene 1, re

Modern automated counts still haven't beaten simple hand-programmed counting scripts



Clark Chapman wrote the first automated crater counting script more than 40 years ago.



What would you do?